3D Perspective towards the Modelling and Applications of Cadastral Building Data in Taiwan

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SUMMARY

In recent years, Taiwan has been actively advancing a nation digital twin project that leverages multi-dimensional geographic information technology. Three-dimensional building data has been identified as a fundamental component of the national base map. In addition to the 3D building data generated through photogrammetry and topographic mapping, data managed by cadastral organizations is considered a valuable resource for representing 3D buildings from a property rights perspective. Currently, Taiwan has amassed over 8 million building registration records, each uniquely identified by a building number. This paper examines the strategies for establishing and sharing building numbers and their corresponding 3D spatial representations to enhance their utility in GIS-based applications. Two distinct types of 3D representations have been developed: building number positioning points and cadastral building property model. Based on Taiwan's existing building registration framework, a schema for 3D cadaster buildings has been designed utilizing CityGML 2.0 Application Domain Extensions (ADE), which offers advantages in terms of alignment with international standards and the facilitation of open format data sharing. The proposed schema, characterized by clear semantics, is capable of accommodating the modeling of various types of building, including apartments and high-rise structures. Furthermore, new construction procedures have been integrated into the existing building registration process. Cadastral building data in the future will not only feature three-dimensional spatial representations but also improve interoperability through standardized models. This advancement is expected to yield significant benefits by fostering innovative multi-purpose applications of three-dimensional building information and supporting the development of the national spatial data infrastructure.

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1. INTRODUCTION

The digital cadastre system in Taiwan is overseen and administered by the Ministry of the Interior (MoI) and has experienced several phases of development. The existing cadastre database serves as a comprehensive national repository that encompasses both cadastral maps and building data. The cadastral map data is based on two-dimensional parcels and associated land adminstration information, while the building data is presented in a tabular format containing registration details. Although this building registration data may be supplemented by building plane survey data to visually depict the spatial extent of individual properties, its content nevertheless lacks the recording of geographic coordinates.

In Taiwan, the integration of three-dimensional geographic information has emerged as a pivotal component of the national base map. The absence of spatial representation for the current 8 million building registration records has impeded the optimal application of geographic information system technology and the effective support of cadastral data-related activities from a locational standpoint. In response, the MoI has initiated the "Towards 3D Smart Land - National Base Map Spatial Data Infrastructure Project," which provides financial assistance to municipalities and county (city) governments nationwide for the implementation of the "Three-Dimensional Cadastral Building Integration Project." The overarching objective is to realize the three-dimensional representation of nationwide cadastral buildings within a five-year timeframe, spanning from 2021 to 2025.

The building number serves as a unique identifier assigned to each registered building property, corresponding to the three-dimensional spatial extent of that property. In this paper, the spatial representation is conceptualized in two distinct manners: as positioning points or as a cadastral model of building properties. From a geometric representation standpoint, building number positioning points abstractly represent the spatial extent of a property through a singular point defined by three-dimensional coordinates. When integrated with the attributes of the building registration data, this representation can adequately fulfill the requirements for various three-dimensional cadastral applications pertaining to buildings. Conversely, the cadastral building property model employs the concept of boundary representation to spatially delineate the three-dimensional extent of various building units. This three-dimensional representation is based upon the property boundaries documented in the building plane survey data, as well as the default heights or actual floor heights derived from completion work charts. Unlike the building number positioning points, the three-dimensional spatial representation is further categorized into two types of property units: main buildings and ancillary buildings, allowing for the establishment of spatial relationships with the building or floor in which they are situated. Given the substantial number of registered buildings accumulated over the years, the retroactive construction of a nationwide three-dimensional database necessitates significant financial investment(more than 100 million US dollars). The Ministry of the Interior's promotion plan encompasses two primary strategies: commencing in

2021, all newly constructed houses will generate their three-dimensional cadastral building property model data through newly established registration procedures and systems, while buildings registered prior to 2021 will predominantly utilize building number positioning points, as illustrated in Figure 1.

Figure 1. Building number positioning points and cadastral building property model

The objective of this study is to establish a three-dimensional framework for cadastral buildings in Taiwan, enabling the modelling and sharing of various types of building from a standardized perspective. The creation of a data model that accommodates three-dimensional cadastral information presents significant challenges, necessitating the consideration of factors such as data redundancy, application dependencies, scalability, integrity and consistency, as well as security (Višnjevac et al., 2019). Furthermore, the dynamic nature of cadastral data requires continuous updates, which in turn necessitates ongoing modifications to the three-dimensional cadastral building data (Olfat et al., 2021). CityGML 2.0 (OGC, 2012), an internationally recognized standard advocated by the Open Geospatial Consortium (OGC), offers semantically rich three-dimensional models for various urban phenomena. However, its building module currently lacks semantic considerations from the perspective of property rights (Saeidian et al., 2022; Góźdź et al., 2014). In their work, Góźdź et al. (2014) integrated CityGML with the Land Administration Domain Model (LADM) in the context of developing a three-dimensional cadastre in Poland, leveraging the spatial representation capabilities of CityGML alongside the legal property concepts inherent in LADM. They proposed classes such as "PL_LegalSpaceBuilding," "PL_3DParel," and "PL_CadastralParcel," establishing relationships with the "_AbstractBuilding" class of CityGML 2.0. Given that Taiwan's existing cadastre system has been operational for an extended period and that current regulations and database mechanisms already incorporate semantic considerations pertinent to land management and registration, this paper aims to investigate the design of a three-dimensional cadastral building data model following existing mechanisms and international standard technologies (CityGML). The proposed model will also be pragmatically operational, thereby laying the groundwork for future cross-domain sharing and integration.

2. CADASTRAL BUILDINGS IN TAIWAN

2.1 Models of building property rights

In Taiwan, the procedure for building registration encompasses an optional survey of the building, which can be requested by property owners. Since this is a necessary document for housing loans, almost all newly built houses will apply for it. The building plane survey data serves as a reference for documenting the spatial extent of property rights, each identified by a unique building number. The initiative to develop a three-dimensional (3D) property rights model utilizing building plane survey data commenced a decade ago (Chiang, 2012). The results of the paper-based surveys are digitized through scanning, and a vector data file is manually created based on individual floors. The recorded data encompasses the spatial representation of both the main building and ancillary building, along with the registration data corresponding to each building number on the respective floor. The 3D representation is achieved by extruding the height of each building unit, which is determined either by the predetermined height of a single floor or by the specific floor heights indicated in the building completion chart. For multi-story buildings, the 3D data for each floor is stacked accordingly. Given that the original building plane survey data lacks geographic coordinates, the positioning of the 3D buildings is established by referencing reliable geospatial sources, such as cadastral maps, aerial photographs, and digital elevation models (DEM). Furthermore, more detailed 3D building models can be enhanced through on-site surveys, including drone aerial photography and the placement of indoor furnishings.

The advancement of building survey methodologies has led to the substitution of traditional building unit surveys with digital surveying techniques. This transition allows the cadastral office to simultaneously fulfill legal requirements for the generation of building plane survey data and the establishment of three-dimensional (3D) cadastral building property right information. Given that the newly developed system is seamlessly integrated into the existing building registration process, it is anticipated that all future constructions will be accompanied by corresponding 3D cadastral building data.

2.2 Building number position point

The substantial expenses associated with the construction of property models render it impractical to retroactively create such models for the over 8 million registered buildings established prior to 2021. The objective of the "Building Number Positioning Point Project" is to assign three-dimensional coordinates to each building number, thereby facilitating their application within three-dimensional Geographic Information Systems (3DGIS). Each building number is mandated to possess a singular positioning point (TGIS, 2022). Initially, the central coordinates of the land parcel housing the building are calculated as a preliminary value. Subsequently, manual adjustments are made by referencing scanned building plane survey data and other credible sources, such as electronic map building data, to ascertain the most accurate locations for each building number. For instance, in cases where a building comprises multiple floors, each with distinct building numbers, the initial values may coincide and require further adjustment. The final positioning outcomes must adhere to specific topological constraints, such as remaining within the parcel and the building itself. Additionally, building numbers within the same structure require manual adjustments to ensure consistency across different floors. The elevation of the building positioning points is estimated based on the respective floor, with the elevation determined by the vertical center of that floor. In instances where the actual floor height is unavailable from the building's completion chrat, a predetermined floor height is utilized instead. In cases where multiple floors within a single building share a single building number (e.g., a townhouse), only one positioning point corresponding to the floor nearest to the ground is recorded (first floor or basement). Ultimately, the generated building number positioning points are linked to building registration data and disseminated in shapefile format. It is anticipated that the establishment of building positioning point data for buildings registered prior to 2021 will be completed by 2025. At that juncture, all cadastral buildings in Taiwan will be geospatially represented either by building number positioning points or by cadastral building property models.

As the data creation process is executed by local cadastral offices nationwide, the National Land Surveying Center (NLSC) has initiated a verification project aimed at assessing and ensuring the quality of the completed data. The project's objective is to identify prevalent error patterns within operational procedures and to develop a toolkit to enhance verification efficiency. Given that the data creation process necessitates a significant allocation of human resources to master newly developed systems, comprehensive guidelines providing standard operating procedures have been established, including the "Building Number Positioning Operation Guidelines" and the "S09 Platform Verification Tool" (TGIS, 2023). The principal processes and verification operations are elaborated as follows.

(1) Phase 1 Inspection: Systematic checks with registration data.

This phase entails a thorough evaluation to ascertain the consistency of the building number positioning points with the building registration data. This includes an examination of the coordinate system, attribute schema, as well as the quantity of building numbers.

(2) Phase 2 Inspection: Evaluation of Location and Attributes.

In this phase, an initial assessment is conducted to determine whether the location of the building number positioning points adheres to the requisite topological constraints. For instance, it is essential that the positioning points are situated within the designated land and the corresponding buildings.

(3) Phase 3 Inspection: Review from a Property Perspective.

This phase is subdivided into two components: automated checks, which identify overlapping building number point locations at the same level, and manual verification, which addresses tasks that cannot be assessed automatically. This includes evaluations such as confirming that the building number positioning points are accurately located within the appropriate building units, among other considerations.

All data submitted by local cadastral offices must undergo a verification process via the S09 platform to guarantee data quality. Table 1 enumerates the types of errors that can be automatically detected by the S09 platform, with each error type distinguished by a specific color to facilitate operator awareness. For a more in-depth examination of manual errors, please consult the project report (TGIS, 2023).

Table 1. The automatic check patterns of errors by S09

Pattern	Explanation	Color
Not within parcel	Building number positioning point is not within the related parcel.	pink
Not within building	Building number positioning point is not within the building polygons in the electronic maps.	light blue
Attribute mismatch	The attribute value of building number do not match the content in the cadastral database.	blue
Share the same coordinates	Building numbers at the same floor share the same coordinates.	orange
Redundant/repeated positioning points	Every building number corresponds only one positioning point.	green
Multiple errors	More than two types of errors found	red

3. SCHEMA DESIGN

3.1 Design strategy

This paper introduces a model for the three-dimensional (3D) cadastral building framework in Taiwan. Building upon the results of this design, a preliminary draft of the "3D Cadastral Building Data Standard" is currently being developed, with the intention of submitting it as a domain data standard to the National Geographic Information System (NGIS) standardization committee in 2025. Among the standards that have already been published, the "3D Building Model Data Standard" was primarily created for 3D building data derived from aerial or terrestrial surveying methods. Since this standard is implemented in accordance with CityGML 2.0, a similar design approach is employed in the "3D Cadastre Building Data Standard" to enhance interoperability. Although CityGML includes a building module, it falls short in adequately representing the diverse cadastral characteristics from a semantic perspective. The model for building property rights encompasses various units associated with the building, such as individual buildings, floors, primary buildings, and ancillary buildings, each possessing distinct semantics and fulfilling different roles in the management of building registration data.

To effectively integrate existing cadastral systems while adhering to open GIS standards, the application schema for the 3D Cadastre Building Data Standard is developed utilizing CityGML Application Domain Extensions (ADE) (Biljecki et al., 2018). Furthermore, it is essential to account for the information pertinent to the registration of property rights for buildings in Taiwan. A feature class based on building numbers is also proposed. The design of the application schema must thoroughly consider the interrelationships among classes, including buildings, floors, building numbers, primary buildings, and ancillary building, to ensure accurate modeling of various types of building in real world. Proposals for application schemas concerning the cadastral building property model and the positioning points of building numbers are presented. While the design of the former application schema is based on the CityGML 2.0 standard, the latter is developed using GML 3.1.1, as CityGML 2.0 does not accommodate the use of 3D points for modeling Level of Detail 0 (LOD0) buildings.

Figure 2 illustrates the UML application schema for the property rights model, which encompasses four feature classes: "Property Building," "Floor," "Property Unit," and "Building Number Management Unit." The design and semantics associated with each class are elaborated upon below:

- The "Property Building" class is utilized for modeling the characteristics of the property of a single building.
- The "Floor" class captures the spatial extent and attributes pertinent to an individual floor within a building.
- The "Building Number Management Unit" class documents the spatial extent and attributes associated with a specific building number. This feature class serves as a fundamental reference in the proposed schema, necessitating the establishment of relationships with other feature classes, including "Property Buildings," "Floors," and "Property Units."
- The "Property Unit" class records the spatial extent and attributes of both the primary and ancillary buildings corresponding to a specific building number.

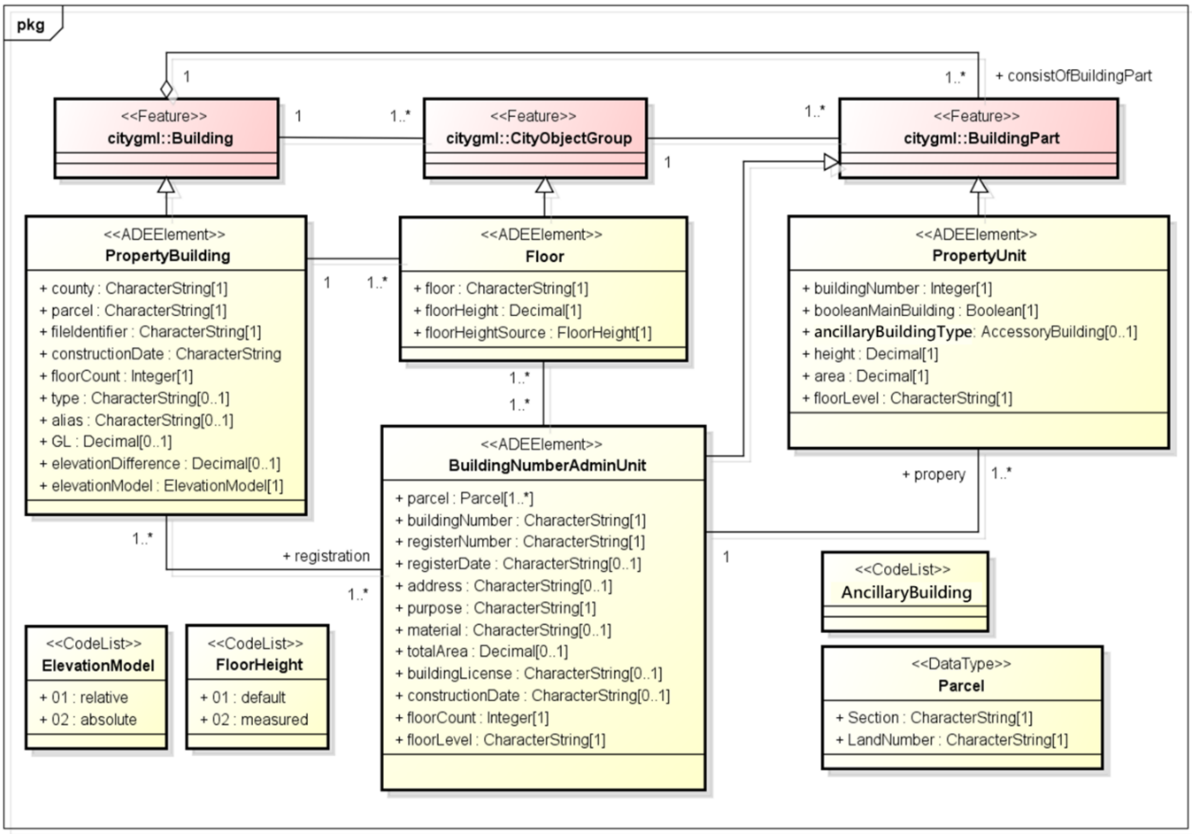

Figure 2. Schema for the building property right model

3.2 Property Building

The "Property Building" class is designed to inherit from the "Building" class as defined by the CityGML standard. Given that the "Building" class itself inherits from the "_AbstractBuilding" class, the "Property Building" class similarly inherits the attributes of the "_AbstractBuilding" class. Additional attributes specific to the "Property Building" class include: county/city, section code, building number, completion date, number of floors, building type, building alias, ground level (GL), elevation difference, and elevation model. The "GL" attribute records the elevation of the terrain on which the building is situated, expressed in orthometric height, utilizing the coordinate reference system TWVD2001 (NLSC, 2001). This information provides useful height reference to the building data.

3.3 Floor

The polygon-based building unit information recorded in the building plane survey data is systematically organized by individual floors. A three-dimensional model can be created by extruding the polygon based on either a predetermined height or the actual height indicated in the completion work chart. The combination of the outer wall, ceiling, and floor defines a three-dimensional volume referred to as the "floor." This classification of "floor" is derived from the "CityObjectGroup" class within the CityGML standard and includes attributes such as class, function, and usage, as well as relational elements like groupMember and geometry. The CityObjectGroup class is a subclass of CityObject, which employs the groupMember attribute to record the CityObjects (including Building, BuildingPart, or other CityObjects) that form the structural components of a specific floor within the three-dimensional building model. Furthermore, the floor class encompasses attributes such as floor, floor height, and floorHeightSource. The floorHeightSource attribute utilizes a codelist to indicate whether the height information is based on a standard floor height (e.g., 3.3 meter) or the actual measured floor height.

3.4 Building number management unit

The class of "Building Number Management Unit" records the spatial extent and attributes identified by a unique building number. This class is designed to inherit from the BuildingPart class of CityGML. As the BuildingPart class inherits from the AbstractBuilding class, thus the class of "Building Number Management Unit" also inherits from the AbstractBuilding class. Additional designed attributes include parcel, buidlingNumber, registerNumber, registerDate, address, purpose, material, totalArea, buildingLicense, constructionDate, floorCount and floorLevel.

3.5 Property Unit

In accordance with the prevailing cadastral regulations, the property associated with a building identified by a unique building number encompasses two categories: the main building and ancillary building. The "property unit" class is intended to extend the BuildingPart class as defined in CityGML. Given that the BuildingPart class itself derives from the AbstractBuilding class, the "property unit" class similarly inherits from the AbstractBuilding class. This property unit class is responsible for documenting the spatial extent and attributes of both the main and ancillary buildings. The attributes defined for this class include the building number, booleanMaineBuilding, the type of ancillary building, height, area, and floor level. The boolean attribute serves to specify whether the property described is classified as a main building or an ancillary building.

Each feature class is modeled at a specific Level of Detail (LOD) in accordance with CityGML 2.0 (refer to Table 2, where "X" denotes not applicable). Both the property building class and the floor class are represented as LOD3 three-dimensional surface data. The property units class encompasses both LOD3 and LOD4 three-dimensional representations. The selection of LOD4 is contingent upon the type of ancillary building; for instance, indoor ancillary buildings are modeled as LOD4 spatial units. Consequently, the building number management unit is capable of representing both main and ancillary buildings in either LOD3 or LOD4. The modeling approach may utilize MultiSurface or classes with specific semantics, such as WallSurface, InteriorWallSurface, FloorSurface, CeilingSurface, and RoofSurface.

Table 2. Designed feature classes and LOD

Class name	Inherited class	LOD 3	LOD 4
PropertyBuilding	Building	MultiSurface	X
floor	CityObjectGroup	MultiSurface	X
PropertyUnit	BuildingPart	MultiSurface	MultiSurface
BuildingNumber AdminUnit	BuildingPart	MultiSurface	MultiSurface

3.6 Establishment of Building Number Positioning Points

In order to facilitate the distribution of point-based building number positioning data, the "BuildingNumber" class has been developed. The corresponding UML diagram is illustrated in Figure 3. The geometric data pertaining to the building number positioning class refers to the GM_Point class as outlined in ISO 19107. The attributes incorporated into this design are derived from building registration data and encompass parcel, buildNumber, address, registerDate, registerReason, purpose, material, totalArea, floorCount, floorLevel, constructionDate, buildingLicense, floorHeightSource, and elevationModel. Given that the elevation of the building number positioning point is contingent upon its reference source, two additional attributes have been introduced: the source of floor height, which differentiates between default and actual floor heights, and elevationModel, which specifies whether the height information is relative to the terrain.

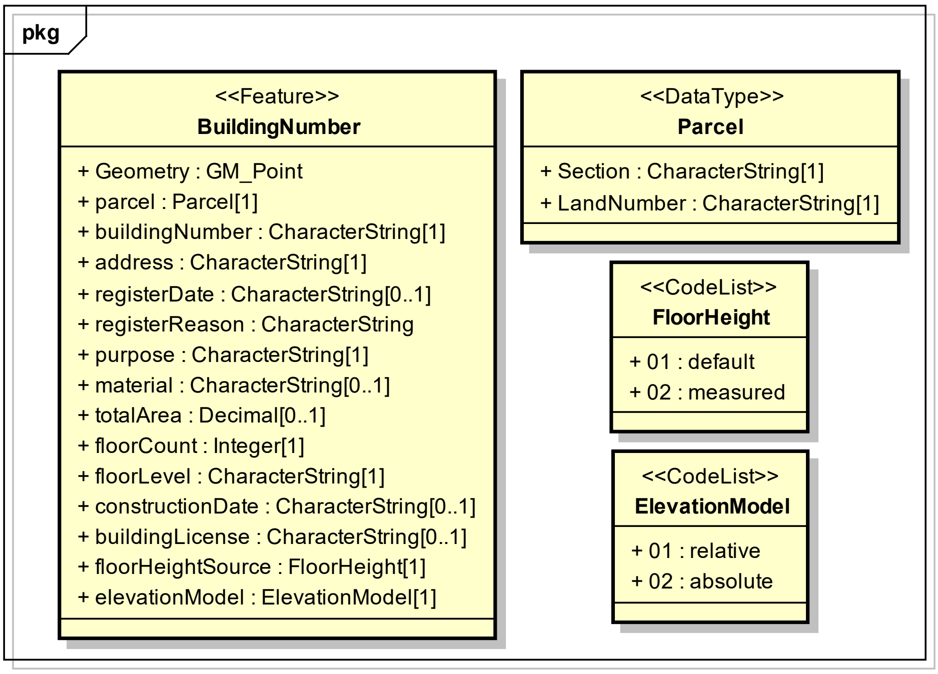

Figure 3. Schema for the building number position point

4. CASE ANALYSIS AND APPLICATION

4.1 Case analysis

This study develops an XML schema in accordance with the principles of UML application schema and XML schema. The resulting data file is structured to represent each property building as a singular CityModel, which encompasses multiple cityObjectMembers. One cityObjectMember is designated to document a property building, while the others provide details regarding individual floors. This modeling approach is applicable to all types of buildings. The property building is intended to encapsulate the overall property of the entire building. In addition to its inherented attributes, it incorporates the <register> tag to establish a connection with the corresponding "BuildingNumberAdminUnit". This design facilitates geospatial referencing for individual buildings or households, utilizing the street address attribute from the "BuildingNumberAdminUnit".

To accurately depict the complete structure and aesthetic of individual buildings, it is advisable to extract the exterior walls corresponding to each building units in order to create a three-dimensional representation. Each floor of a building is modeled using the "LOD3MultiSurface". An individual floor is modelled as a CityObjectGroup, which utilizes the groupMember attribute to document the distinct wall surfaces. The exterior walls are categorized as WallSurface, ceilings as CeilingSurface, and floors as FloorSurface. Special considerations are required for the roof and the first floor; the roof is represented by RoofSurface rather than CeilingSurface, while the first floor is represented as GroundSurface instead of FloorSurface.

Case Study 1: Detached House or Townhouse

This case study examines a three-story townhouse. In the recording data, <CityModel> comprises four <cityObjectMember> elements: one designated for <PropertyBuilding> and three allocated for <Floors>. The gml:id attribute serves to uniquely identify each building within the dataset. Multiple instances of the <consistOfBuildingPart> tag are employed to document the associated <PropertyUnit>, with each <PropertyUnit> representing either a main building or an ancillary building. Additionally, the corresponding <BuildingNumberAdminUnit> for the described building is recorded. In the case of a townhouse, which possesses a singular building registration, it is documented only once.

Case 2: Congregate Housing

In Taiwan, residential structures are classified into three categories based on their height and the availability of elevators: "apartments," which lack elevators and consist of five floors or fewer; "condominiums," which are equipped with elevators and contain ten floors or fewer; and "high-rise buildings," which also have elevators and exceed eleven floors. The proposed model is applicable for modeling all three types of buildings, with the primary distinction being the number of associated building numbers and property units. In this particular case, the structure comprises seven floors, leading to the inclusion of eight <cityObjectMember> elements within the <CityModel>, one designated for <PropertyBuilding> and seven for <Floor>. A notable difference between apartment buildings and other residential types, in contrast to detached houses, lies in the number of associated building numbers and more complicated interrelationships among the building units. Even a single floor may correspond to multiple building property units, each identified by distinct building numbers. Provided that the interrelationships among various building property units are effectively established, the reading and processing of data can be conducted seamlessly.

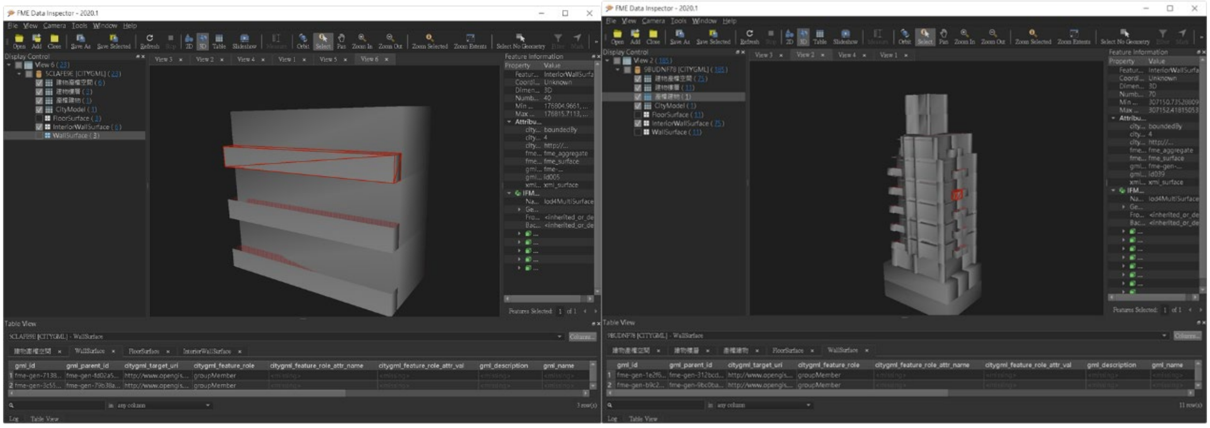

Figure 4. 3D property buildings for case 1 and 2

4.2 Applications

The intricate relationship between human economic activities and buildings facilitates the development of diverse applications when these elements are integrated. The realization of the 3D cadastral building plan not only marks a significant milestone in the evolution of Taiwan's cadastral system but also serves as a pivotal element in the advancement of national geographic information.. This research addresses the issue from the cadastral building perspective, proposing the establishment of building units with 3D spatial representations, which can lead to significant advancements across various application domains.

(1) Advancements in Land Administration Applications

The findings of this study present a 3D model that aligns with the existing building registration system in Taiwan. This model not only fulfills the requirements of the current building registration process but also facilitates various applications within 3D contexts. These applications may widely include the representation of actual 3D property boundaries, the analysis of 3D spatial relationships, the composition of 3D relationships among building units, the promotion of real estate activities, and the execution of visibility analyses. Furthermore, 3D buildings can be integrated with parcel data, thereby providing more accurate references for regional planning. Notably, the establishment of 3D building points and property models allows for a closer integration of land administration tasks related to buildings with geographic information system technology.

(2) Diverse Representations

Together with the 3D building data from photogrammetry and topographic maps, 3D cadastral buildings serve as a reliable source of multiple representations for the national base maps. These 3D buildings are characterized by clear specifications and are established according to standardized design procedures, which help mitigate the risk of erroneous applications. Beyond their property-related implications for building units, the compositional relationships of these units can yield building content that diverges from visual representations, thereby enhancing the flexibility of building data provision, including information pertaining to buildings, floors, and individual units.

(3) Cross-Domain Applications

The establishment of spatial representations for property units, facilitated by unique building numbers and associated addresses, offers a significant advantage by overcoming the current limitations of primarily visual displays and the challenges associated with accurately determining address locations. Three-dimensional cadastral building data is currently the only dataset capable of providing precise positioning for individual household, thereby advancing existing applications that are restricted to approximate 2D geocoding service to a more accurate 3D spatial positioning or distribution. This enhancement can substantially improve decision-making quality, particularly in densely populated metropolitan areas. When decision-making applications can evolve from being confined to a specific building (or a number of buildings) to accurately identifying the location of designated addresses, including further accessing information about nearby addresses and conditions within an entire building segment, it can yield direct benefits for applications such as building management, disaster prevention and response, logistics, and healthcare. Moreover, through the association of domain identifiers, a substantial amount of domain-specific data related to buildings can acquire 3D coordinates, thereby strengthening the applications of three-dimensional geographic information.

5. CONCLUSION

The advancement of national spatial data infrastructure has identified three-dimensional (3D) building models as a significant innovation. However, the transition from two-dimensional (2D) to 3D modeling presents considerable challenges, primarily due to the absence of technological solutions and the substantial volume of analog data accumulated over the years. This paper examines the strategies for the creation and sharing of 3D cadastral building data in Taiwan. Specifically, a 3D cadastral building property model and the corresponding building number positioning points have been developed to accommodate registered building data from both before and after 2021. These models are implemented using open technology to promote the development of interoperable applications. The proposed schema categorizes building units into four classes, based on the extension of the CityGML 2.0 Building module. A notable advantage of 3D cadastral building data is its capacity to provide household-level geospatial reference, which enhances the potential for smart city and digital twin applications through precise positioning. Additionally, the design ensures that 3D building data in Taiwan, derived from both survey and cadastral domains, is compatible with CityGML 2.0 standards. Building numbers can also be linked to various identifiers, such as street addresses, land numbers, and tax identification numbers, thereby facilitating a wide range of value-added applications, including real estate price registration, Internet of Things integration, logistics delivery, disaster prevention and relief, business registration, and social security systems. This interconnectedness has the potential to generate extensive and far-reaching impacts.

REFERENCES

Biljecki, F., Kumar, K., & Nagel, C. (2018). CityGML application domain extension (ADE): overview of developments. Open Geospatial Data, Software and Standards, 3, 1-17.

Chiang, H. (2012). Data Modelling and Application of 3D Cadastre in Taiwan. In Proceedings of the 3rd International FIG Workshop on 3D Cadastres, 137-158, Shenzhen, China.

Góźdź, K., Pachelski, W., van Oosterom, P., Coors, V. (2014). The possibilities of using CityGML for 3D representation of buildings in the cadastre. In Proceedings of the 4th International FIG Workshop on 3D Cadastres, 9-11, Dubai, UAE.

OGC. OGC City Geography Markup Language (CityGML) Encoding Standard 2.0.0, Standard OGC 12-019. Open Geospatial Consortium. 2012.
Olfat, H., Atazadeh, B., Badiee, F., Chen, Y., Shojaei, D., Rajabifard, A. (2021). A Proposal for Streamlining 3D Digital Cadastral Data Lifecycle, Land, 10, 642.
Saeidian, B., Rajabifard, A., Atazadeh, B., & Kalantari, M. (2022). Data lifecycle of underground land administration: a systematic literature review. Survey Review, 55(392), 396–415.
Taiwan Geographic Information Society, (2023). 2023 Government Procurement for Investigation and Process Optimization of the Building Numbers Positioning Point Examination System, Final Report. Ministry of the Interior Project. (in Chinese)
Taiwan Geographic Information Society, (2022). 2022 Government Procurement for Investigation and Process Optimization of the Build Number Positioning Evaluation System, Final Report. Ministry of the Interior Project. (in Chinese)
Višnjevac, N.; Mihajlović, R.; Šoškić, M., Cvijetinović, Ž., Bajat, B. (2019). Prototype of the 3D cadastral system based on a NoSQL database and a Javascript visualization application. ISPRS Int. J. Geo-Inf. 8, 227.

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